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PROJECT ADMINISTRATION DATA SHEET

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Project No. G-42-606 GTRI/~~GIT~~ DATE 2 / 14 / 84

Project Director: Dr. Edward J. Rinalducci School/~~Lab~~ Psychology

Sponsor: University of Dayton Research Institute
Dayton, Ohio 45469

Type Agreement: P.O. No. RI-31695 under Gov't Prime F33615-81-C-0005

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Title: Azang Lat Support

ADMINISTRATIVE DATA

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Defense Priority Rating: DO1C9

Military Security Classification: ______

(or) Company/Industrial Proprietary: ______

RESTRICTIONS

See Attached ------ Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with none proposed.

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Date 1/9/85

Project No. G-42-606 School/~~Lab~~ Psych.

Includes Subproject No.(s) N/A

Project Director(s) Dr. Edward Rinaldducci GTRC / ~~GIT~~

Sponsor University of Dayton Research Institute

Title Azang Lat Support

Effective Completion Date: 9/30/84 (Performance) 9/30/84 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [XX] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
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AZANG LAT SUPPORT

FINAL REPORT

February 1, 1984-September 30, 1984

Submitted by: Edward J. Rinalducci, Michael J. Patterson, Michelle Forren, and Robert Andes, Jr.

School of Psychology
Georgia Institute of Technology
Atlanta, GA 30332

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AZANG LAT SUPPORT

FINAL REPORT

February 1, 1984-September 30, 1984

Edward J. Rinalducci, Michael J. Patterson, Michelle Forren, and Robert Andes, Jr.

School of Psychology
Georgia Institute of Technology
Atlanta, Georgia 30332

ABSTRACT

The present research was primarily concerned with the perceptual factors associated with low altitude flight, and was directed towards the assessment of the ability of pilots to accurately estimate altitude using a psychophysical technique. Pilot and non-pilot observers in the proposed research were required to estimate altitude from photographs taken at different altitudes over six terrain areas in the Southwestern United States. These terrain areas differed in various cue factors such as object density, objects of known size, vertical development, and shading. In general, the results indicated that pilots were more accurate in their estimates than non-pilots, but both groups showed a similar pattern of responding to the different terrains. The ability of pilots and non-pilots to estimate altitude appeared to depend upon the presence of certain cue factors. Recommendations are made relative to the assessment of pilots' ability to estimate altitude before and after low altitude flight training.

INTRODUCTION

Important visual factors are involved in the training of pilots for low level flight operations. The research reported here was particularly concerned with the assessment of the ability of pilots to accurately estimate altitude using a psychophysical technique. Information variables required for low altitude flight include perceived altitude, perceived distance to terrain features, and the identification of terrain features. Visual cue factors which affect these information variables include object density, terrain features of known size, terrain features with vertical development, and shading. Pilot and non-pilot observers were employed in the present study to estimate altitude from photographs taken at different altitudes over six terrain areas in the Southwestern United States. These terrain areas differed in the various cue factors mentioned above. In addition, altitude estimates of non-pilot observers using photographs taken with a standard 55 mm lens were compared with photographs taken with a wide angle 35 mm lens as the later offered a wider field of view but with some minification and distortion. Thus, the first experiment examined altitude estimations for six terrain environments for pilot and non-pilot observers. The second experiment examined the responses of non-pilot observers using two types of lenses for the six terrain environments. A third brief and somewhat related experiment is reported in the Appendix which examines altitude estimation for CIG scenes vs. actual visual scenes.

METHODS

Subjects

Twenty-five F-4 pilots of the 128th Tactical Fighter Group stationed at Dobbins AFB in Marietta, GA volunteered to be in the first experiment. However, twenty-two pilots were retained for the data analysis as three of them appeared not to follow directions. The 22 pilots in this study had an average flying time of approximately 2698 hours with a standard deviation of 1212. Flying time for the pilots ranged from 450 to 5500 hours. They had flown a variety of military aircraft including not only the F-4 but also the A-7, A-10, F-100, F-105, and the F-15, as well as some commercial types of aircraft such as the Boeing 727. The responses of the pilots were compared to 22 non-pilot observers using the same stimulus materials. The non-pilot observers were obtained from the undergraduate population at Georgia Tech. The second experiment compared the responses of the 22 non-pilots using photographs taken with a standard lens to 29 non-pilot subjects (also obtained from the undergraduate population of Goergia Tech) viewing the same terrain environments but taken with a wide-angle lens. All subjects used in the present research were male.

Materials

Stimulus materials consisted of 35 mm color slides of the terrain in the Southwestern United States taken from a helicopter with a standard 55 mm lens and a 35 mm wide-angle lens. Nine types of terrain were chosen, but three had to be eliminated due to either missing altitudes or changing shadows for each altitude. The different terrain environments are listed and described below.

(A) Flat, medium density, known size terrain features.
(B) Rolling hills, heavily forested.
(C) Rolling hills, low vegetation density, no known size terrain features.
(D) Rolling hills, grassland, no known size features.
(E) Rough hills, medium density.
(F) Flat desert, low medium density.
(G) Salt flat, no known size features.
(H) Extremely rough hills.
(J) Known size buildings, but two lowest altitudes whited out due to the helicopter prop wash.

Conditions A, B, C, F, G, and H were used in the study as these scenes were, in general, found to be most adequate for providing a range of complexity in terrain features and textures. The results of the study will present the six different environment conditions arranged according to an apparent scene complexity (i.e., G, F, A, C, H, and B). Each terrain environment was taken at eight different altitudes ranging in 0.13 log unit steps from 50 to 400 feet (i.e., 50, 68, 90, 122, 167, 221, 299, and 400 feet AGL) so as to encompass the low-level domain. Black and white photographs of these terrain environments are shown in the Appendix for the altitude condition of 122 ft.

Procedure

At the beginning of each session, the experimenter explained the purpose of the research and that a sequence of slides were to be presented. Each terrain environment had eight slides for the eight different altitudes. The slides were presented three times in a random order for a total of twenty-four presentations for each terrain environment. As only about five subjects were run at any one time, the order of the terrain environments was randomized for each group. The presentation order for the different environments was counter balanced for each group.

The psychophysical procedure employed in the present study was a variation of the method of magnitude estimation using the free-modulus technique (Engen, 1972; Stevens, 1975). This method has been previously employed by this investigator and his associates. It has proved to be an effective and economical approach to the assessment of simulator visual displays, and has been shown to be related to simulator flying performance (DeMaio, Rinalducci, Brooks, & Brunderman, 1983; Patterson & Rinalducci, 1984; Rinalducci, 1983; Rinalducci, DeMaio, Patterson, & Brooks, 1983; Rinalducci, Patterson, & DeMaio, 1984). Subjects were given response sheets (see Appendix) and were told that when the first slide appeared, they were to estimate the altitude above the ground (AGL) shown. Subjects were told that altitude estimates for subsequent slides were to be made relative to the first. That is, if the estimated altitude for the first slide was 100 feet and the second slide appeared to have been taken from an altitutde twice as high, the second estimate should be 200 feet, and so on, for succeeding slides. The pilot and non-pilot observers were not told the exact range of altitudes involved in order to avoid biasing the obtained results at the extremes (i.e., 50 and 400 feet). Each slide was presented for eight seconds with the interval between the slides being only the cycle time of the projector (Kodak Ektagraphic). Each slide for a given altitude and terrain feature was presented three times. There were three trials consisting of eight different altitudes for each of the six terrain environments. The first trial was treated as practice and the altitude estimates from the second and third runs only were analyzed. Instructions to the subjects are also given in the Appendix.

Questionnaires were also employed, not only to obtain an indication of flying experience of each of the pilots, but also to assess the cues used to estimate altitude for both pilot and non-pilot observers. Instructions to subjects and the questionnaire used in this research are presented in the Appendix. The same questionnaire and instructions were employed for all subjects whether they were pilots or non-pilots.

Experimental Design

The experimental design used in the first experiment (hereafter referred to as experiment 1) was a 2 x 6 split-plot factorial design (2 levels of flying experience x 6 terrain environments). This study compared the responses of pilot vs. non-pilot observers for altitude estimation for the six different terrain environments. The second experiment (hereafter referred to as experiment 2) compared only non-pilot observers' estimation of altitudes using terrain environments taken with either a normal or standard

55 mm lens or a 35 mm wide-angle lens. Again a 2 x 6 split-plot factorial design was employed (2 types of lens x 6 terrain environments). Split-plot designs were used in experiments 1 and 2 and in previous studies in order to insure that there was no confounding of the between subjects variables (i.e., flying experience and lens type).

RESULTS

As indicated above, the first slide presentation sequence was treated as practice and the altitude estimates from the second and third runs only were analyzed. A linear regression function was determined relating log estimated altitude to log actual altitude for each of the six terrain environment conditions. The least squares technique was used to solve for the slope and y-intercept of the linear regression function. The dependent measure analyzed was the slope of the function which is the exponent (n) of the power function (S = kI) obtained for each subject. The exponents were treated as individual data points. The values of the y-intercept were not analyzed. In terms of the power function, an exponent (or slope of the log-log plot of the linear regression function) of 1.0 is indicative of accurate estimation of altitude. An exponent greater than 1.0 is indicative of expansion or overestimation of changes in altitude and an exponent of less than 1.0 is indicative of compression or underestimation of changes in altitude. The data for both experiments 1 and 2 are shown in Figure 1 and in Table 1. As indicated above the terrain environments are presented in the order G, F, A, C, H, and B according to an apparent increasing complexity and density of terrain features in the visual scene.

Table 1

Power Function Exponents as a Function of Environment, Flight Experience, and Lens Type

	Environments					
Flight Experience	G	F	A	C	H	B
Pilots	0.640	1.13	1.13	0.559	0.916	0.887
Non-Pilots	-0.030	1.013	0.706	0.281	0.755	0.654
Non-Pilots*	0.094	1.089	0.859	0.087	1.019	0.624

*Wide-angle lens employed

In addition to Figure 1 and Table 1, Tables 2 through 8 show the data analyzed for both experiments using split-plot ANOVAs and Scheffe multiple comparison tests. Table 2 shows the split-plot ANOVA for pilot and non-pilot data as a function of terrain environment. Tables 2, 4, 5, and 7 show the analyses particularly relevant to pilot and non-pilot comparisons. In general, pilots were shown to be better than non-pilots in their ability to estimate altitude. This was particularly true for environments G and A.

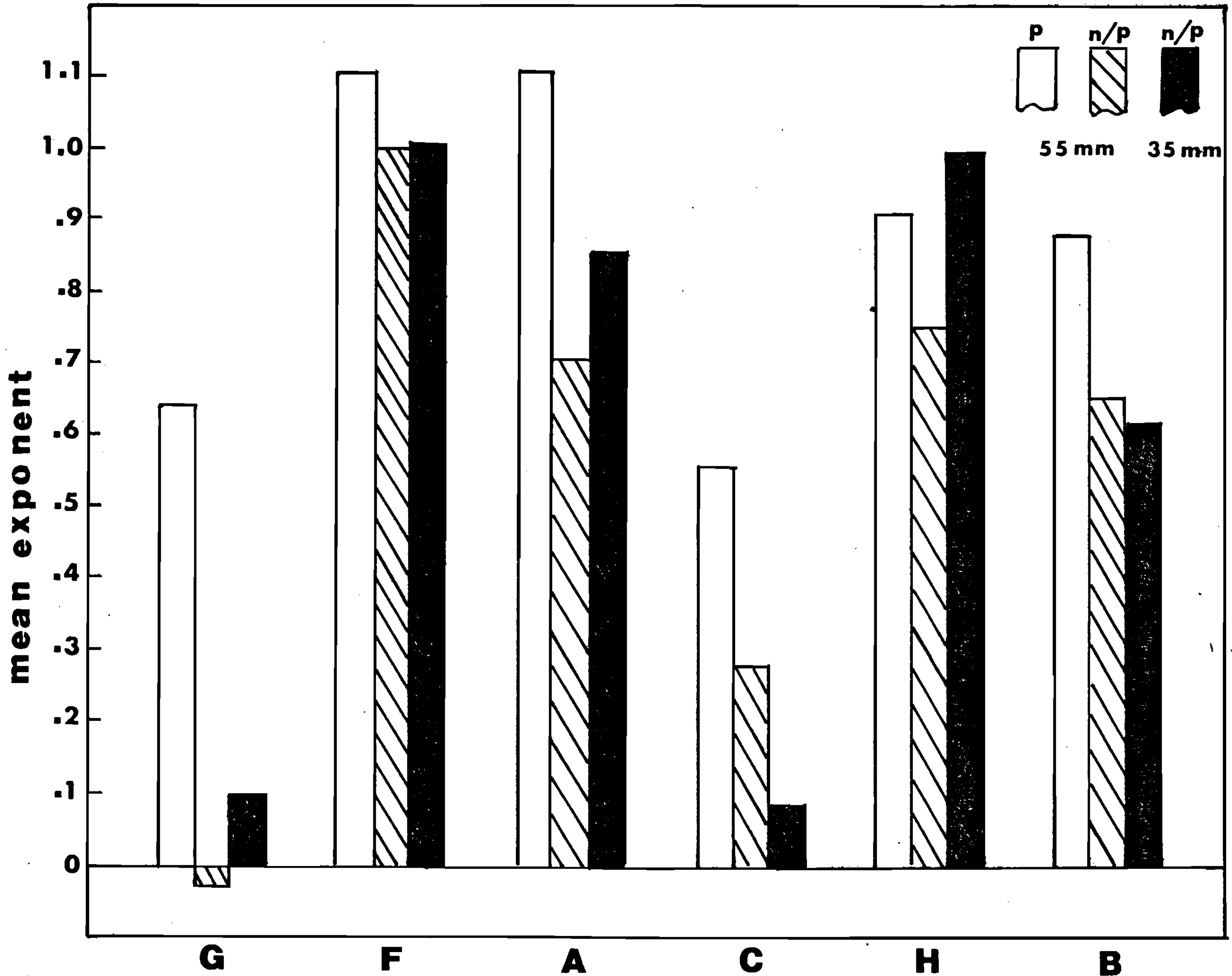

Fig. 1. Power function exponents as function of terrain environment, flight experience, and lens type.

In terms of the wide-angle vs. the standard lens slides there were no significant differences between the two types of lenses as shown in Table 3 and Table 7. There were significant differences for the environments condition and for the environment by subject interaction. These findings suggest that there were differences between the different terrain environments and that these differences were dependent upon flight experience (i.e., pilots vs. non-pilots).

The results indicated that for pilots, environment G (salt flats) produced smaller power functions than did the other environments (in particular, G is less than A). Scheffe tests indicated no differences between G, H, and B, and there were no differences between F, A, H, and B. Environment C also produced low estimates, but this was probably due to an illusory cue for real altitude caused by the photographs being taken above a ridge. For non-pilots, environment G produced lower exponents than environments F, A, H, and B. Again, environment C also produced lower estimates of altitude for non-pilots.

Based on the obtained results, it would appear to be useful to eliminate environment C and to retain environments G, F, A, H, and B for low-level flight training and assessment purposes. The results also suggest that since there are no differences between slides taken with a standard lens vs. a wide-angle lens for non-pilots, either type of lens may be employed for acquiring actual visual scenes for initial training and assessment.

Table 2

Split-Plot ANOVA for Pilot vs. Non-Pilot Data

Source	Sum of Squares	DF	Mean Square	F	Prob.
Subject	6.68782	1	6.68782	29.75	<0.001
Error	9.66695	43	0.22481		
Envi.	19.85345	5	3.97069	30.77	<0.001
ES	2.33985	5	0.46797	3.63	0.0036
Error	27.74893	215	0.12906		

Table 3

Split-Plot ANOVA for Non-pilot Subjects and Normal vs. Wide-Angle Lens

Source	Sum of Squares	DF	Mean Square	F	Prob.
Lens	0.32393	1	0.32393	1.05	<0.313
Error	15.09939	49	0.30815		
Envi.	40.83443	5	8.16689	61.09	<0.001
ES	1.59339	5	0.31868	2.38	0.0390
Error	32.75510	245	0.13369		

Table 4

Scheffe Tests of Pilots for the Different Environments

	G	F	A	C	H	B
G	-	19.221*	24.356*	7.615	6.876	9.191
F		-	0.001	21.833*	3.089	5.504
A			-	27.759*	3.826	7.716
C				-	9.867	12.606*
H					-	0.091
B						-

*$p<0.05$. DF = 5 and DF2 = 40. N = 23.

Table 5

Scheffe Tests for Non-pilot Data for the Different Environments

	G	F	A	C	H	B
G	-	40.799*	19.793*	3.086	20.766*	18.724*
F		-	9.552	67.893*	5.494	48.051*
A			-	20.976*	0.185	0.330
C				-	20.626*	22.326*
H					-	0.969
B						-

*$p<0.05$. DF1 = 5 and DF2 = 38. N= 22.

Table 6

Scheffe Tests for Non-pilots using a Wide-Angle Lens

	G	F	A	C	H	B
G	-	52.637*	30.146*	0.004	42.189*	16.498*
F		-	5.780	189.754*	0.491	6.285
A			-	101.283*	2.407	35.303*
C				-	128.612*	82.883*
H					-	82.883*
B						-

*p<0.5. DF1 = 5 and DF2 = 52. N = 29.

Table 7

Scheffe Tests for Pilot vs. Non-pilot Data for Each Environment

Env G: F = 17.120*

Env F: F = 1.126

Env A: F = 17.227*

Env C: F = 8.218

Env H: F = 1.884

Env B: F = 10.890

*p<0.05. DF1 = 5 and DF2 = 39. N = 23 (pilots) and N = 22 (non-pilots).

Table 8

Scheffe Tests for Non-pilot Data for Normal vs. Wide-Angle Lens*

Env G: F = 0.287

Env F: F = 0.221

Env A: F = 0.822

Env C: F = 2.071

Env H: F = 2.143

Env B: F = 0.044

*$p<0.05$. DF1 = 5 and DF2 = 45. N = 22 (normal s) and N = 29 (wide-angle lens).

The data obtained indicated that there was no correlation between flying experience (in hours flying time of the pilots) and the size of the exponent of the power function. The correlation was on the order of 0.04. As previously noted, there was considerable flying experience which involved a wide range of military and non-military aircraft.

More interesting results were obtained to questions concerning the certainty with which the observers were able to estimate altitude from the stimuli used, and the cues used to estimate altitude (See Tables 9 and 10, respectively). As Table 9 shows pilots were somewhat more certain of their altitude estimates than were non-pilots. Table 10 shows a comparison of cues used by pilots and non-pilots for scenes obtained with a normal 55 mm lens. Only cues for which at least 5% of the responses given either by pilots or by non-pilots are included in Table 10. These cues include (1) the size of foilage, trees, etc., (2) the size of objects of known size, (3) the distance to the horizon, (4) the angle to the ground, (5) a change in the position of a specific object (i.e., a reference point), and (6) a "feeling" of altitude.

In general, both pilots and non-pilots tended to employ the same cues although pilots tended to use somewhat more technical terms than non-pilots. The use of similar cues by both groups for the estimation of altitude suggests that pilots early in their training probably use the same cues as they will employ later but with a lesser degree of certainty. Also confidence or certainty of the altitude estimates should increase with training and experience.

Table 9

Certainty of Altitude Estimates for Pilots and Non-Pilots

	Certainty		
Subjects	None	Some	Average
Pilots	4.3%	43.5%	52.2%
Non-Pilots	9.1%	59.1%	31.8%

Table 10

Comparison of Pilots and Non-Pilots for Cues used in Estimating Altitude

Cue	Pilots (23)	Non-Pilots (22)
Size of foilage, trees, etc.	23.8%	15.3%
Size of objects of known size	23.8%	15.3%
Distance to horizon	11.1%	8.3%
Angle	7.9%	6.9%
Change in place of a specific object (i.e., a reference point)	1.6%	8.3%
"feeling"	3.2%	6.9%

DISCUSSION

In general, the results suggest that in terms of altitude estimation, flying experience is a necessary component to enable an observer to adequately utilize the information that may be available in a low-level flight environment. The data shown in Tables 1 and 7 and in Figure 1 for terrain environments G and A indicate that pilots are more accurate than non-pilots in estimating altitude. This is in keeping with previous research by this investigator and his associates (Rinalducci et al., 1984). Similarly, Table 9 shows that there is a tendency for pilots to have somewhat more certainty as to their altitude estimates. As previously indicated, the terrain environments G, F, A, H, and B would appear to be the most useful for pilot training and assessment. Environment C, should probably be eliminated as it tends to confuse observers due to an illusory cue.

Future research might be directed towards an examination of the relative changes in performance as a function of piloting experience. As a pilot acquires more flight experience, it is expected that a correspondingly greater degree of accuracy, as reflected in an increase in the exponent of the power function, should be obtained in his estimations. Further studies are needed in order to indicate the minimal number of flight hours required in order to have a given level of accuracy in altitude estimation. Another study which is related to the present experiments concerns the use of dynamic presentations of the same scenes to both pilot and non-pilot observers. Rinalducci et al. (1984) showed that pilots when exposed to a dynamic visual scene which was lacking in visual cues were still able to more accurately estimate altitude than non-pilot observers. Several terrain environments (e.g., G, F, and A) could be obtained using a video or motion picture camera mounted on a helicopter. These films could then be run higher speeds in order to simulate faster fixed-wing aircraft. The dynamic scenes could then also be employed in pilot training and assessment.

Another variable which may affect altitude estimation is mental workload. Time estimation has been shown to be affected by a second task (Ogden, Levine, & Eisner, 1979). One way to test the hypothesis that mental workload has an effect on altitude estimation is to have the observer simultaneously make altitude estimations while engaged in a complex psychomotor task. This would be particularly relevant to performance within the low-level visual environment.

Another direction for research in this area might examine the possible relationship between contrast sensitivity and altitude estimation. Screening could be conducted on a large number of non-pilot subjects initially, and depending on the outcome, it might then be considered for application to pilot observers.

An additional study might involve the selective masking of certain terrain features in real-world scenes (i.e., photographs) or high-fidelity CGI could indicate the relative importance of classes of terrain features and objects within the visual environment necessary to accurately estimate altiude. Such findings would have importance to the design of a training program and should aid in optimizing transfer of training from presentation of visual scenes to the pilot or within a flight simulator.

With regard to the two types of display formats used (i.e., standard vs. wide-angle lens), the type of lens employed to obtain actual scenes does not appear to introduce a noticeable difference in distortions in the scenes or in terms of altitude estimations. However, the perception of any distortion introduced by certain lenses may be dependent upon the number of hours of flying experience in the low-level regime. It is possible that because non-pilots were used in this portion of the study responses to any distortions or a wider field of view provided by the wide-angle lens might not be revealed. Additional research is needed to investigate in a factorial manner, the effect of differing fields of view and levels of object distortion on altitude estimation.

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APPENDIX

A. Questionnaire.

Name:____

Rank:______________________________

Telephone No.____________________

Address:____

Years in Service: Active________; Reserve or National Guard________

Total Hours Flying Time:___________

Aircraft flown (type and hours):____
____
____
____

Aircraft now flying:_______________

With what certainty were you able to estimate altitude from the stimuli used?

1___no certainty

2___some certainty

3___average certainty

4___considerable certainty

5___complete certainty

What cues did you use to help you estimate altitude from the stimuli used? List the most important cue first, the next most important second, and so on.

____
____
____
____
____
____
____

B. Data Sheet.

DATA SHEET

NAME:______________________________ NO.:__________

Condition:______

1.__________	7.__________	13.__________	19.__________
2.__________	8.__________	14.__________	20.__________
3.__________	9.__________	15.__________	21.__________
4.__________	10.__________	16.__________	22.__________
5.__________	11.__________	17.__________	23.__________
6.__________	12.__________	18.__________	24.__________

Condition______

1.__________	7.__________	13.__________	19.__________
2.__________	8.__________	14.__________	20.__________
3.__________	9.__________	15.__________	21.__________
4.__________	10.__________	16.__________	22.__________
5.__________	11.__________	17.__________	23.__________
6.__________	12.__________	18.__________	24.__________

Condition______

1.__________	7.__________	13.__________	19.__________
2.__________	8.__________	14.__________	20.__________
3.__________	9.__________	15.__________	21.__________
4.__________	10.__________	16.__________	22.__________
5.__________	11.__________	17.__________	23.__________
6.__________	12.__________	18.__________	24.__________

C. Instructions to Subjects.

In the following slide presentations, I want you to judge the altitude above ground level. These scenes have been taken from a helicopter and represent a low level altitude in a range somewhere between 0 and 600 feet above the ground. The scenes simulate an observer looking forward of an aircraft, engaged in level flight. The terrains represent a variety of conditions including salt flats, forested land, very rough terrain, and so on, taken from the region of the American Southwest.

You are to assign an altitude that you believe you are above the ground in the first slide. For subsequent slides you are to assign an altitude which you believe is appropriate relative to the first slide. For example, if you have assigned 100 to the first slide and believe the next slide represents an altitude which is twice as high, call it 200, if it appears half as high, call it 50, and so on.

Try and make the ratios between the numbers you assign to the altitudes correspond to the ratios between the altitudes. In any slide if you feel you can't readily make a response, make the best estimate that you can make, and try to be consistent.

Are there any questions?

D. Subject Data from Experiments 1 and 2.

Pilot Observers Using 55mm Lens

ENVIRONMENT

Subject #	G	F	A	C	H	B
1-1	.91	.99	1.06	.65	26	1.01
1-2	.88	.87	.93	.60	.61	.88
1-3	1.12	1.04	1.57	.43	.56	1.11
1-4	.59	2.40	2.21	- .37	.39	1.26
1-5	.58	1.36	1.61	.72	.64	1.05
2-1	.60	.77	.77	.24	.81	.90
2-3	.58	.71	1.30	.43	.74	.64
2-4	.67	1.02	1.29	.71	1.03	.83
2-5	1.10	.80	1.13	.34	.88	.83
3-1	.22	.76	1.04	.44	.95	.69
3-2	.75	1.16	1.10	.88	1.06	.61
3-3	.30	.72	.82	.42	.76	.64
3-5	.66	1.23	1.35	.82	1.03	.61
4-1	.55	1.17	.97	.99	1.12	.74
4-2	.61	.97	1.15	.40	.70	.59
4-3	.75	1.35	.58	.66	1.05	1.05
4-4	.67	.81	.89	.64	.94	1.07
4-5	.20	2.22	1.04	.36	2.02	1.31
5-1	.47	.74	1.15	.50	.88	.90
5-2	.10	1.22	1.02	.67	.96	.77
5-3	.51	.96	.67	.63	1.25	1.06
5-4	1.46	1.52	1.15	1.66	1.68	1.18
5-5	.47	1.28	1.18	.04	.75	.69
Σ	14.75	26.07	25.98	12.86	21.07	20.42
$\bar{x}$	.64	1.13	1.13	.559	.916	.887
S.D.	.312	.437	.343	.374	.380	.220

Non-pilot Observers Using 55mm Lens

ENVIRONMENT

Subject#	G	F	A	C	H	B
NP 1-1	-0.088	0.997	1.265	0.365	0.960	0.660
NP 1-2	-0.052	0.499	0.207	0.419	0.667	0.721
NP 1-3	0.744	1.542	0.793	0.819	1.142	0.998
NP 1-4	0.320	0.607	0.459	0.889	1.063	1.056
NP 2-1	0.387	0.764	0.792	0.343	0.002	0.685
NP 2-3	0.718	1.170	0.447	0.101	0.374	0.404
NP 2-4	-0.607	0.790	0.774	0.225	0.808	0.854
NP 3-1	-1.177	0.590	0.935	0.172	0.758	0.697
NP 3-2	0.920	0.652	0.069	0.351	0.649	0.630
NP 3-3	-0.311	0.886	1.044	0.023	-0.369	0.138
NP 4-1	0.245	1.254	0.288	-0.002	0.583	0.894
NP 4-2	-0.538	0.975	1.182	0.504	1.395	0.516
NP 4-3	0.923	0.945	0.675	0.161	0.748	0.652
NP 4-4	-0.876	1.506	0.407	0.129	1.034	1.081
NP 4-5	0.553	1.051	0.699	0.013	0.803	0.477
NP 5-1	0.304	1.525	0.979	0.633	1.172	0.846
NP 5-2	-0.535	1.262	0.166	0.011	0.798	0.232
NP 7-1	0.320	0.941	0.839	0.437	0.579	0.624
NP 7-2	-0.600	0.642	0.615	-0.202	1.110	0.669
NP 7-3	-1.189	1.325	1.068	0.242	0.419	0.725
NP 7-4	-0.974	1.12	0.745	0.141	0.671	0.241
NP 7-5	0.850	1.235	1.085	0.407	1.238	0.590
N = 22 Σ	-2.503	22.278	14.533	6.181	16.604	14.39
$\bar{x}$	- .03014	1.013	.706	0.281	0.755	0.654
S.D.	.681	0.309	.333	0.264	0.398	0.247

Non-pilot Observers Using Wide-Angle Lens

ENVIRONMENT

Subject#	G	F	A	C	H	B
NP 6-1	1.128	1.090	1.133	0.094	1.106	0.699
NP 6-2	0.491	1.923	1.027	0.139	1.618	0.756
NP 6-3	-1.009	1.439	0.692	-0.048	0.532	0.774
NP 8-1	0.445	1.516	1.171	0.060	1.210	0.917
NP 8-2	0.924	1.141	0.934	0.016	0 329	0.801
NP 8-3	-0.575	1.344	1.241	-0.005	0.957	0.498
NP 8-4	-0.731	0.691	0.385	0.137	1.014	-0.097
NP 9-1	0.469	1.235	1.158	0.052	1.749	0.509
NP 9-2	-0.389	0.518	0.570	-0.119	0.848	0.557
NP 9-3	0.204	1.187	0.187	0.052	0.733	0.557
NP 10-1	-1.272	1.375	0.667	0.039	1.061	0.855
NP 10-2	-0.812	0.927	0.418	-0.059	0.518	0.536
NP 10-3	-0.192	0.633	0.753	0.113	1.145	0.798
NP 10-4	-0.133	0.889	0.741	0.181	0.810	0.857
NP 11-1	-0.291	1.451	0.778	0.028	1.444	0.705
NP 11-2	-0.444	1.166	1.080	0.017	0.679	0.673
NP 11-3	0.718	1.185	1.322	0.010	1.155	0.734
NP 11-4	0.307	0.678	0.617	0.080	0.897	0.850
NP 12-1	0.723	1.654	0.888	0.001	1.495	0.691
NP 12-2	-0.577	1.280	1.052	-0.080	1.389	0.517
NP 12-3	0.816	1.196	0.890	0.070	1.263	0.857
NP 12-4	0.230	0.972	0.788	0.094	0.853	-0.128
NP 14-1	0.855	1.004	0.751	0.122	1.841	0.900
NP 14-2	0.552	0.990	0.680	0.137	1.312	0.662
NP 14-3	0.159	0.707	0.237	0.037	0.797	0.605
NP 15-1	1.150	1.152	1.945	0.750	1.151	0.653
NP 15-2	0.009	0.786	0.991	0.534	1.008	0.626
NP 15-3	-0.046	0.323	0.422	0.031	0.263	0.033
NP 15-4	0.028	1.138	1.395	0.0355	0.376	0.695
Σ	2.737	31.590	24.913	2.5185	29.553	18.090
$\bar{x}$	0.0944	1.089	0.859	0.087	1.019	0.624
S.D.	0.637	0.347	0.370	0.168	0.401	0.263

E. Experiment 3: Actual Visual Imagery vs. Computer Generated Imagery in Simulated Flight Environments.

This study was carried out by Robert C. Andes, Jr. as part of his Senior Research Project in the School of Psychology at the Georgia Institute of Technology. The study is presented in an edited form.

ABSTRACT

The present study investigated the effects of varying levels of visual scene detail in terms of accuracy of altitude estimation. Six environments were presented (i.e., three actual or real-world scenes and three computer-generated environments.

INTRODUCTION

Due to increased risk associated with training in advanced high-performance aircraft, there is a need to simulate critical real-world situations. In particular, a great deal of time and effort has been invested in creating a high fidelity simulation of the visual flight environment for selected aspects of low-level flight training. With the advent of advanced computer capabilities, the applicability of computer generated imagery to critical situation flight training needs to be evaluated. The primary concern is whether or not computer generated displays accurately model the real world for certain critical situation simulation training. The hypothesis being examined in this study is if computer generated image (CGI) content can be controlled in terms of scene content, similar amounts of scene content should yield similar altitude estimation performance curves for both actual scenes and CGI.

METHODS

Materials

The basic method utilized in this study is that used by Rinalducci et al (1983) and is presented in the main body of this report. Stimulus materials were 35mm slides of six different visual environments. Three of these were actual scenes from the Southwestern United States and three were computer generated images.

Due to a wide variance in the nature of the stimulus items, a suitable metric was required to measure the visual scene content. It was hypothesized that the factors of terrain object type and object density were the most important for accurate estimation of altitude. Therefore, the amount of detail, the independent variable, was based on a combination of terrain object type and object density. Detail was formulated using a subjective estimation technique developed for this experiment. The estimation technique utilized a square texture grid (Wolpert, Owen, and Warren, 1983) superimposed onto each one of the stimulus slide types (for approximately a 100 ft altitude condition) from a projected 15 ft viewing distance. The factors considered in object detail were as follows: terrain object type which was a qualitative variable accounting for the "type" of object in the scene (e.g., bushes, trees, buildings, mountains, etc.) and object density which was the average relative quantity of total objects in a grid reference square. Table 11 shows the object detail analysis breakdown for the six scenes used in the study.

Table 11*

Stimluli for Altitude Estimation Study

Type	Scene	Obj type	Obj density	Detail
actual	A (plain, city)	high	high	high
	B (forest)	low	high	med
	G (salt flat)	low	low	low
CIG	C (flat plain)	low	low	low
	D (plain, pyr)	medium	medium	medium
	E (mountains, pyr)	medium	high	high

*abbreviations for object is obj and for inverted pyramids is pyr.

The CGI were taken from the visual system of the Advanced Simulator for Pilot Training located at Williams AFB, AZ. The highest detail environment (Condition E) consisted of a valley floor with mountains (approximately 4000 ft) and inverted pyramids with white bases randomly placed on the valley floor. The pyramids had a density of about 700 per square mile with heights of 30, 50, and 75 ft. The intermediate detail condition (Condition D) consisted of a valley floor with inverted pyramids with white bases. The pyramids were placed at an average separation of 1500 ft.

The minimal detail condition (Condition C) consisted only of the textured floor of Condition D. Eight altitudes were used which ranged from 50 to 400 ft AGL.

For the actual scene visual stimuli, 35mm slides were taken by personnel of HRL, Williams AFB. Similar to the CGI stimuli, each terrain environment was taken at eight different altitudes ranging from 50 to 400 ft AGL. The highest detail environment for the actual visual scenes (Condition B) consisted of a a flat plain, a city in the distance, and known size terrain features. The intermediate condition consisted of heavily forested rolling hills and mountains. The minimal detail condition was a salt flat with known size features. The same labels (i.e., A, B, and G) used in experiments 1 and 2 were employed for the actual scene terrain environments in experiment 3.

Subjects

Twenty-eight non-pilot, undergraduate students (18 female, 10 male) at the Georgia Institute of Technology served as subjects for the study.

Procedure

Six groups of subjects were run in the experiment. CIG and actual terrain environments were presented by means of a slide projector, with stimulus and interstimulus intervals for each condition being determined by the cycle time of the projector which was set for an eight second presentation.

At the beginning of each session, the experimenter explained the purpose of the research, and that a sequence of slides would be presented. Subjects estimated altitude using the free modulus variation of the magnitude estimation psychophysical method. This was the same technique used in experiments 1 and 2 in the main body of this report, and it has been shown to be a sensitive technique for the evaluation of simulator display systems (Rinalducci et al., 1983). Presentation order was counterbalanced using a Latin Square method, and the subjects viewed all conditions.

RESULTS

The first display mode sequence was treated as practice and the altitude estimates from the second and third runs only were analyzed. A linear regression function was determined relating log estimated altitude to log actual altitude for each display environment. The least squares technique was used to solve for the slope and y-intercept of the function. The dependent measure analyzed was the slope of the linear regression function, which is the exponent of the power function obtained for each subject. The exponents were treated as individual data points.

A 2 x 3 analysis of variance (Kirk, 1968) was performed on the data. Both variables were within-subjects with two types of sldes at levels of detail. The results indicated that the main effects of scene type (CIG and actual) and detail were significant ($F\ (1, 17) = 10.49$, $p < 0.0032$, and $F\ (2, 54) = 9.96$, $p < 0.0002$, respectively). In addition, a statistically significant interaction between both environment type and detail ($F\ (1, 28) = 23.16$, $p < 0.0001$) was obtained. The results are shown in Table 12 and in Figure 2.

Table 12

Exponents for Actual Visual Scenes and CGI Scenes

Actual Scenes	
Scene A	0.870
Scene B	0.745
Scene G	0.154
CGI Scenes	
Scene C	0.340
Scene D	0.345
Scene E	0.395

Tukey HSD tests (Kirk, 1968) were performed at the 0.05 level to compare statistical differences between levels of detail. The Tukey test was used to clarify the group means between differing types of stimuli. From the analysis it was observed that there were significant differences between CIG and actual scenes for medium and high detail conditions.

There were also significant differences in the actual scene conditions between low and high detail and low and medium detail, but not between medium and high detail. For the CIG scenes there were no significant differences between any level of detail.

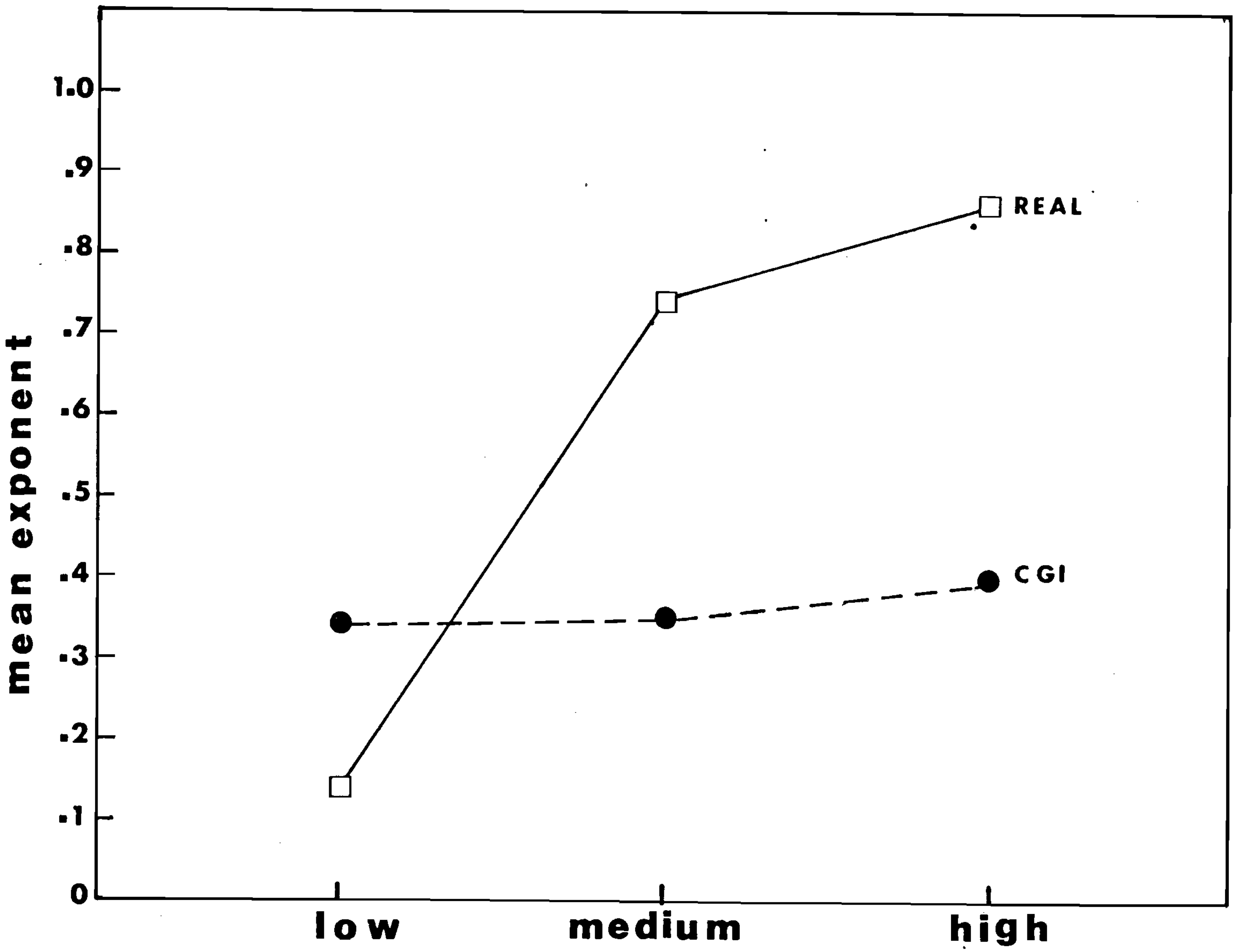

Fig. 2. Exponents for actual and CGI scenes.

In terms of the power function, an exponent of 1 is indicative of perfect estimation. An exponent of greater than 1 indicates overestimation of changes in altitude, and less than 1 indicates an underestimation of changes in altitude. The estimates shown in Figure 1 and Table 12 indicate an underestimation for all subjects across all conditions. The low detail condition for each type of scene showed the greatest degree of underestimation. The most accurate estimation was obtained for the high and medium detail conditions of the actual visual scenes with minimal differences for the low, medium and high detail conditions for CGI stimuli.

DISCUSSION

The results of this study indicate differing levels of performance for subjects viewing actual visual scenes vs. computer generated images. Generally speaking, as detail in the actual visual scene increased altitude estimation increased in accuracy. In contrast, the CGI stimuli did not follow the same progression as the actual visual scene stimuli. That is, the amount of detail for the CGI stimuli used in this study had little effect on the subjects' ability to estimate altitude. This was not found to be the case in previous studies (DeMaio et al., 1983; Rinalducci et al., 1983). One possible reason for the lack of agreement may be that the metric used in this study to assess the amount of detail had some inherent disadvantages. In order to incorporate the existing stimulus materials into the present study, it became necessary to estimate the amount of each type of object, instead of simply using object type as an separate independent variable. This led to a qualitative estimation of the actual visual stimuli due to the large number of object types and densities inherent in each detail level. In summary, no support was found for the hypothesis that accuracy of altitude estimation should increase as the amount of detail increased for the CIG stimuli, although an improvement in performance was found for the actual scene stimuli.

The results of this study do suggest, however, that the amount of detail in the CIG has to be increased in order to approach the accuracy obtained with actual visual scenes from the real world. However, the CIG employed in many simulators are still extremely useful for training purposes particularly in low cue environments. In addition, it may be more appropriate to employ split-plot factorial designs in studies which examine the various cue factors used to estimate altitude. Split-plot factorial designs should help to avoid confounding differences for the between-subjects variables such as flying experience and type of visual scene (e.g., actual vs. CIG).

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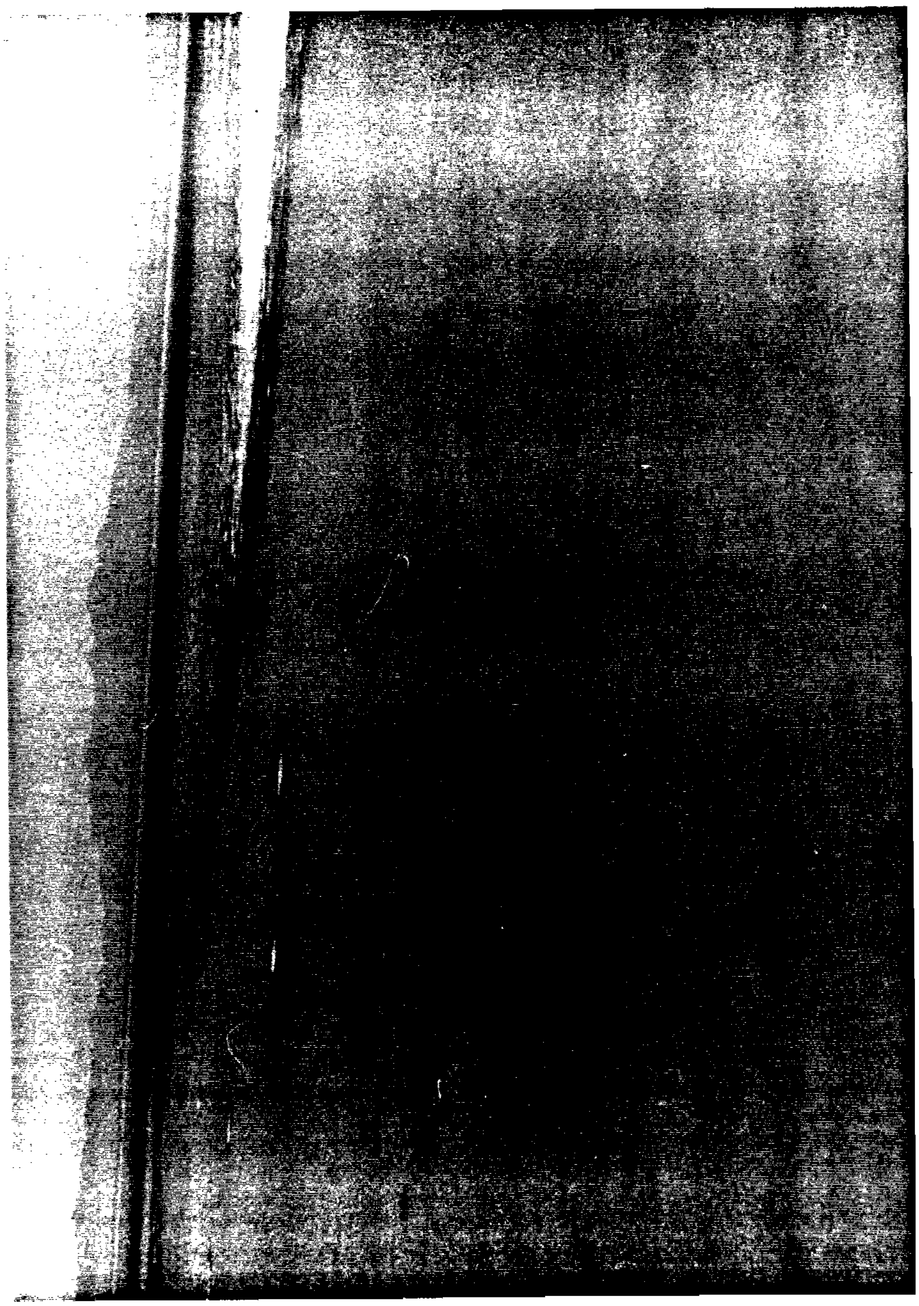
F. Photographs of the Six Terrains Used in Experiments 1 and 2.

Environment G: Salt flat with no known size terrain features.



Environment F: Flat desert with low medium density of terrain features.

Environment A: Flat medium density with known size terrain features.

Environment C: Rolling hills with low vegetation density and no known size terrain features.

Environment H: Extremely rough hills.

Environment B: Rolling hills and heavily forested.